

LISTING OF THE CLAIMS

1 (currently amended): A high-strength hot-dip galvanized steel sheet characterized by: containing, in weight,

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less, and

Al: 0.01 to 2.0%,

balance Fe and unavoidable impurities;

with the relationship among Si, Mn and Al satisfying the following expression,

$Si + Al + Mn \geq 1.0\%$;

a hot-dip plating layer being formed on each of the surfaces of said steel sheet; and

5 to 80% of the surface area of said steel sheet being occupied by Si, Mn and Al oxides when said steel sheet surface is observed with a scanning electron microscope after a hot-dip plating layer is dissolved by fuming nitric acid;

wherein said surface area of said steel sheet occupied by said Si, Mn and Al oxides is on the surfaces of said steel sheet interfacing with said hot-dip plating layer prior to said hot-dip plating layer being dissolved by said fuming nitric acid.

2 (previously presented): A high-strength hot-dip galvanized steel sheet according to claim 1, characterized by further containing, in weight, one or both of

Ni: 0.01 to 2.0% and

Cr: 0.01 to 0.5%.

Claim 3: (canceled.)

4 (previously presented): A high-strength hot-dip galvanized steel sheet according to claim 2, characterized by further containing, in weight, one or more of

Mo: 0.01 to 0.5%,

Cu: 0.01 to 1.0%,

Sn: 0.01 to 0.10%,

V: less than 0.3%,

Ti: less than 0.06%

Nb: less than 0.06%,

B: less than 0.01%,

REM: less than 0.05%,

Ca: less than 0.05%,

Zr: less than 0.05%, and

Mg: less than 0.05%.

5 (currently amended): A high strength hot-dip galvanized steel sheet characterized by, ~~when said steel sheet contains retained austenite and only Mo is added among the elements stipulated in claim 4 according to claim 1:~~

wherein said steel sheet contains retained austenite, and further contains 0.01 to 2.0 wt % Ni, 0.01 to 0.5 wt % Cr and 0.01 to 0.5 wt % Mo;

the relationship among Si, Al and Ni satisfying the following expressions,

$$0.4 (\%) \leq \text{Si} (\%) + \text{Al} (\%) \leq 2.0 (\%),$$

$$\text{Ni} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%), \text{ and}$$

$1/20 \times \text{Ni} (\%) \leq \text{Mo} (\%) \leq 10 \times \text{Ni} (\%);$ and

the volume ratio of said retained austenite in said steel sheet being in the range from 2 to 20%.

6 (currently amended): A high-strength hot-dip galvanized steel sheet characterized by, ~~when said steel sheet contains retained austenite and Cu or Sn is further added in addition to Mo among the elements stipulated in claim 4 according to claim 1:~~

wherein said steel sheet contains retained austenite, and further contains 0.01 to 2.0 wt % Ni, 0.01 to 0.5 wt % Cr, 0.01 to 0.5 wt % Mo, 0.01 to 1.0 wt % Cu and 0.01 to 0.10 wt % Sn,

the relationship among Ni, Cu and Sn satisfying the following expression,

$2 \times \text{Ni} (\%) > \text{Cu} (\%) + 3 \times \text{Sn} (\%);$

the relationship among Si, Al, Ni, Cu and Sn satisfying the following expression,

$\text{Ni} (\%) + \text{Cu} (\%) + 3 \times \text{Sn} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%);$ and

the volume ratio of said retained austenite in said steel sheet being in the range from 2 to 20%.

Claims 7 to 13: (canceled).

14 (new): A high-strength hot-dip galvanized steel sheet according to claim 1, wherein said Si, Mn and Al oxides have a maximum length of 3 μm and said Si, Mn and Al oxides have gaps between them.

15 (new): A method for producing a high-strength hot-dip galvanized steel sheet comprising:

providing a hot-rolled and cold-rolled steel sheet, with said steel sheet containing, by weight,:

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%,

Mo: 0.01 to 0.5%,

Ni: 0.01 to 2.0%,

Cr: 0.01 to 0.5%, and

balance Fe and unavoidable impurities;

with the relationship among Si, Mn and Al satisfying the following expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

the relationship among Si, Al and Ni satisfying the following expressions,

$$0.4 (\%) \leq \text{Si} (\%) + \text{Al} (\%) \leq 2.0 (\%),$$
$$\text{Ni} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%), \text{ and}$$
$$1/20 \times \text{Ni} (\%) \leq \text{Mo} (\%) \leq 10 \times \text{Ni} (\%);$$

annealing said hot-rolled and cold-rolled steel sheet for 10 sec. to 6 min. in a dual phase coexisting temperature range of 750°C to 900°C;

subsequently cooling said annealed steel sheet to 350°C to 500°C at a cooling rate of 2 to 200°C/sec.;

hot-dip galvanizing said cooled steel sheet to form a hot-dip galvanizing layer on each surface of said steel sheet;

cooling said hot-dip galvanized steel sheet to 250°C or lower at a cooling rate of 5°C/sec. or more;

wherein retained austenite in said steel sheet is 2 to 20% by volume ratio.

16 (new): A method for producing a high-strength hot-dip galvanized steel sheet comprising:

providing a hot-rolled and cold-rolled steel sheet, with said steel sheet containing, by weight,:

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%,

Mo: 0.01 to 0.5%,

Ni: 0.01 to 2.0%,

Cr: 0.01 to 0.5%,

Cu: 0.01 to 1.0%,

Sn: 0.01 to 0.10%, and

balance Fe and unavoidable impurities;

with the relationship among Si, Mn and Al satisfying the following expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

the relationship among Ni, Cu and Sn satisfying the following expression,

$$2 \times \text{Ni} (\%) > \text{Cu} (\%) + 3 \times \text{Sn} (\%);$$

the relationship among Si, Al, Ni, Cu and Sn satisfying the following expression,

$$\text{Ni (\%)} + \text{Cu (\%)} + 3 \times \text{Sn (\%)} \geq 1/5 \times \text{Si (\%)} + 1/10 \times \text{Al (\%)};$$

annealing said hot-rolled and cold-rolled steel sheet for 10 sec. to 6 min. in a dual phase coexisting temperature range of 750°C to 900°C;

subsequently cooling said annealed steel sheet to 350°C to 500°C at a cooling rate of 2 to 200°C/sec.;

hot-dip galvanizing said cooled steel sheet to form a hot-dip galvanizing layer on each surface of said steel sheet;

cooling said hot-dip galvanized steel sheet to 250°C or lower at a cooling rate of 5°C/sec. or more;

wherein retained austenite in said steel sheet is 2 to 20% by volume ratio.

17 (new): A method for producing a high-strength hot-dip galvanized steel sheet according to claim 15 or 16 further comprising:

after said cooling of said annealed steel sheet to 350°C to 500°C, retaining said steel sheet in a temperature range of 350°C to 500°C for 10 min. or less.

18 (new): A method for producing a high-strength hot-dip galvanized steel sheet comprising:

providing a hot-rolled and cold-rolled steel sheet, with said steel sheet containing, by weight,:

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%,

Mo: 0.01 to 0.5%,

Ni: 0.01 to 2.0%,

Cr: 0.01 to 0.5% and

balance Fe and unavoidable impurities;

with the relationship among Si, Mn and Al satisfying the following

expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

the relationship among Si, Al and Ni satisfying the following

expressions,

$$0.4 (\%) \leq \text{Si} (\%) + \text{Al} (\%) \leq 2.0 (\%),$$

$$\text{Ni} (\%) \geq 1/5 \times \text{Si} (\%) + 1/10 \times \text{Al} (\%), \text{ and}$$

$$1/20 \times \text{Ni} (\%) \leq \text{Mo} (\%) \leq 10 \times \text{Ni} (\%);$$

annealing said hot-rolled and cold-rolled steel sheet for 10 sec. to 6

min. in a dual phase coexisting temperature range of 750°C to 900°C;

subsequently cooling said annealed steel sheet to 350°C to 500°C at a

cooling rate of 2 to 200°C/sec.;

hot-dip galvanizing said cooled steel sheet;

retaining said hot-dip galvanized steel sheet for 5 sec. to 2 min. in a

temperature range of 450°C to 600°C to form an alloyed hot-dip galvanized layer containing

8 to 15 wt.% Fe on each surface of said steel sheet;

cooling said alloyed hot-dip galvanized steel sheet to 250°C or lower at

a cooling rate of 5°C/sec. or more;

wherein retained austenite in said steel sheet is 2 to 20% by volume ratio.

19 (new): A method for producing a high-strength hot-dip galvanized steel sheet comprising:

providing a hot-rolled and cold-rolled steel sheet, with said steel sheet containing, by weight,:

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%,

Mo: 0.01 to 0.5%,

Ni: 0.01 to 2.0%,

Cr: 0.01 to 0.5%,

Cu: 0.01 to 1.0%,

Sn: 0.01 to 0.10%, and

balance Fe and unavoidable impurities;

with the relationship among Si, Mn and Al satisfying the following expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

the relationship among Ni, Cu and Sn satisfying the following expression,

$$2 \times \text{Ni} (\%) > \text{Cu} (\%) + 3 \times \text{Sn} (\%);$$

the relationship among Si, Al, Ni, Cu and Sn satisfying the following expression,

$$\text{Ni (\%)} + \text{Cu (\%)} + 3 \times \text{Sn (\%)} \geq 1/5 \times \text{Si (\%)} + 1/10 \times \text{Al (\%)};$$

annealing said hot-rolled and cold-rolled steel sheet for 10 sec. to 6 min. in a dual phase coexisting temperature range of 750°C to 900°C;

subsequently cooling said annealed steel sheet to 350°C to 500°C at a cooling rate of 2 to 200°C/sec.;

hot-dip galvanizing said cooled steel sheet;

retaining said hot-dip galvanized steel sheet for 5 sec. to 2 min. in a temperature range of 450°C to 600°C to form an alloyed hot-dip galvanized layer containing 8 to 15 wt.% Fe on each surface of said steel sheet;

cooling said alloyed hot-dip galvanized steel sheet to 250°C or lower at a cooling rate of 5°C/sec. or more;

wherein retained austenite in said steel sheet is 2 to 20% by volume ratio.

20 (new): A method for producing a high-strength hot-dip galvanized steel sheet according to claim 18 or 19 further comprising:

after said cooling of said annealed steel sheet to 350°C to 500°C, retaining said steel sheet in a temperature range of 350°C to 500°C for 10 min. or less.

21 (new): A method for producing a high-strength hot-dip galvanized steel sheet comprising:

providing a steel sheet containing, by weight, :

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%, and
balance Fe and unavoidable impurities;
with the relationship among Si, Mn and Al satisfying the following
expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

subjecting said steel sheet to a treatment in an atmosphere having an
oxygen concentration of 50 ppm or less in a temperature range from 400°C to 750°C;

subjecting said steel sheet to another treatment for 30 sec. or longer in
a temperature range of 750°C or higher in an atmosphere wherein hydrogen concentration,
dew point and oxygen concentration in said atmosphere are defined by H (%), D (°C) and O
(ppm), respectively, with H, D and O satisfying the following expressions,

$$\text{O} \leq 30 \text{ ppm, and}$$

$$20 \times \exp (0.1 \times D) \leq H \leq 2,000 \times \exp (0.1 \times D);$$

hot-dip galvanizing said treated steel sheet.

22 (new): A method for producing a high-strength hot-dip galvanized steel
sheet according to claim 21, wherein said steel sheet further contains, by weight, one or both
of 0.01 to 2.0% Ni and 0.01 to 0.5% Cr, and further containing in weight, one or more of:

Mo: 0.01 to 0.5%,

Cu: 0.01 to 1.0%,

Sn: 0.01 to 0.10%,

V: less than 0.3%,

Ti: less than 0.06%,

Nb: less than 0.06%,

B: less than 0.01%,

REM: less than 0.05%,

Ca: less than 0.05%,

Zr: less than 0.05%, and

Mg: less than 0.05%.

23 (new): A method for producing a high-strength hot-dip galvanized steel sheet comprising:

providing a steel sheet containing, by weight, :

C: 0.03 to 0.25%,

Si: 0.05 to 2.0%,

Mn: 0.5 to 2.5%,

P: 0.03% or less,

S: 0.02% or less,

Al: 0.01 to 2.0%,

Ni: 0.01 to 2.0%, and

balance Fe and unavoidable impurities;

with the relationship among Si, Mn and Al satisfying the following expression,

$$\text{Si} + \text{Al} + \text{Mn} \geq 1.0\%;$$

subjecting said sheet to a treatment for 30 sec. or longer in a temperature range of 750°C or higher in an atmosphere wherein hydrogen concentration and dew point in said atmosphere and Ni concentration in said steel sheet are defined by H (%), D (°C) and Ni (%), respectively, with H, D and Ni satisfying the following expression,

$$3 \times \exp \{ 0.1 \times (D + 20 \times (1 - \text{Ni} (\%))) \} \leq H \leq 2,000 \\ \times \exp \{ 0.1 \times (D + 20 \times (1 - \text{Ni} (\%))) \};$$

hot-dip galvanizing said treated steel sheet.

24 (new): A method for producing a high-strength hot-dip galvanized steel sheet according to claim 23, wherein said steel sheet further contains, by weight, one or more of:

Cr: 0.01 to 0.5%

Mo: 0.01 to 0.5%,

Cu: 0.01 to 1.0%,

Sn: 0.01 to 0.10%,

V: less than 0.3%,

Ti: less than 0.06%,

Nb: less than 0.06%,

B: less than 0.01%,

REM: less than 0.05%,

Ca: less than 0.05%,

Zr: less than 0.05%, and

Mg: less than 0.05%.

25 (new): A method for producing a high-strength hot-dip galvanized steel sheet according to claim 15 or 18, wherein said steel sheet further contains, by weight, one or more of:

Cu: 0.01 to 1.0%,

Sn: 0.01 to 0.10%,

V: less than 0.3%,

Ti: less than 0.06%,

Nb: less than 0.06%,

B: less than 0.01%,

REM: less than 0.05%,

Ca: less than 0.05%,

Zr: less than 0.05%, and

Mg: less than 0.05%.

26 (new): A method for producing a high-strength hot-dip galvanized steel sheet according to claim 16 or 19, wherein said steel sheet further contains, by weight, one or more of:

V: less than 0.3%,

Ti: less than 0.06%,

Nb: less than 0.06%,

B: less than 0.01%,

REM: less than 0.05%,

Ca: less than 0.05%,

Zr: less than 0.05%, and

Mg: less than 0.05%.